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AN ECONOMIC ASSESSMENT OF THE IMPACT OF THE CITRUS TRISTEZA VIRUS ON THE FLORIDA GRAPEFRUIT INDUSTRY

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Abstract: **A disease confronts the Florida citrus industry: citrus tristeza virus. Although it is likely that tristeza has been present in the Florida peninsula for some time, the arrival of the brown citrus aphid (*Toxoptera citricida*) means that an efficient vector is now present to spread the disease through Florida. It is well known that grapefruit (*Citrus paradisi*) planted on sour orange rootstock (*Citrus aurantium*) is a vulnerable scion/rootstock to the tristeza virus.**

The incidence of the citrus tristeza virus has been on the rise, notably in some of the southern and western areas of the state, as well as parts of the Indian River region. A relatively large percentage of Florida grapefruit, as well as a smaller but significant percentage of sweet oranges (*Citrus sinensis*) , is planted on sour orange rootstock. The strain of tristeza found in Florida is expected to kill infected trees on sour orange rootstock.

In this paper, estimates made by horticulturists on the proportion of grapefruit planted on sour orange rootstock are used to make grapefruit production projections for the next 10 yrs, under the assumption that lost trees are replanted.[1] The production estimates are then incorporated into a pricing model,[2] and price forecasts

[1] The production forecasts were made by the Florida Department of Citrus.

[2] The pricing model was developed at the University of Florida. See Pana (1991) or Ali et al. (2000) for more detail on the pricing model.

are made for upcoming seasons. The pricing model accounts for domestic and export markets for fresh and processed grapefruit products.

Review of Florida grapefruit trees and acres. As of 1999, Florida had 13 million grapefruit trees on 121,300 acres (Table 1). The grapefruit tree population has nearly doubled since 1966. In the mid 1980s, the tree population decreased by about 1 million due to freezes, resulting in a decline in grapefruit production. Strong on-tree prices during this period led to an increase in tree plantings, and by the mid 1990s the tree population was about 15 million. A series of large crops were produced in the 1990s and on-tree prices declined sharply, resulting in a contraction of the tree population to approximately 13 million.

The 1999 tree population is about 20% more than that in the late 1970s and early 1980s when Florida grapefruit production reached 50 million boxes plus, suggesting that Florida still has a sufficient number of grapefruit trees to produce crops of well over 50 million boxes. In addition, the 1999 grapefruit tree population is somewhat young in age, with about 40% of the trees being eight yrs old or less. As trees mature they tend to yield more fruit per tree, suggesting maturation of the present tree population alone may result in increased production. However, grapefruit trees today are on fewer acres than in the 1970s and early 1980s, suggesting that these trees may not have the space to reach yield levels observed in the past in mature groves. Average grapefruit trees per acre, across all tree age classes, have increased from less than 70 in 1966 to106 in 1999. For newly planted grapefruit groves, the average ranges from 120 to 130 trees per acre. This increase in tree density may limit yields per tree and overall grapefruit production.

Florida grapefruit trees on sour orange rootstock. The Bureau of Citrus Budwood Registration (BCBR) is a source of data on the distribution of new plantings by scion and rootstock. These data show percentages of nursery trees on sour orange rootstock, by year set. These percentages can be applied to total trees and acres on all rootstocks, by year, reported by the Florida Agricultural Statistics Service (FASS), to obtain estimates of grapefruit trees and acres on sour orange root stock. Using this approach, the BCBR estimated that 18% of total citrus acreage and 32% of the grapefruit acreage had trees on sour orange in 1998. From 1998 to 1999, the grapefruit tree and acre populations declined by 7.9% and 8.7%, respectively. Assuming 50% of these declines involved grapefruit on sour orange root stock gives an estimate of 26% of Florida's grapefruit trees on this rootstock in 1999 (Table 2). Assuming grapefruit trees on sour orange rootstock are distributed across the regions of the state according to each region's share of the state's trees, by age, an estimated 29% of the grapefruit trees in the Indian River region as of 1999 were on this rootstock versus 20% in the other areas of the state. The estimated percentages of acres on sour orange rootstock were slightly higher than the estimated percentages of trees.

A survey of grapefruit on sour orange rootstock in the Indian River region, by Hebb and Stover (Indian River Research and Education Center, Ft. Pierce, FL, 1999), indicates that more grapefruit may be on sour orange than suggested by the BCBR data. Based on this survey, an estimated 48% of the grapefruit in the Indian River region is on sour orange. The reason given for this discrepancy is that until tristeza appeared, trees on sour orange had the highest survival rates among all of the rootstocks used in Florida. As most of the sour orange trees were planted 10 to 25 yrs ago (in the 1980s and earlier; relatively few trees on sour orange rootstock have been planted in the last 10 yrs), tree survival would be an important factor. Thus, it was assumed in the analysis that 48% of the trees in the Indian River area and 20% of the grapefruit trees in the remainder of the state are planted on sour orange rootstock.

Most of the grapefruit trees on sour orange rootstock in existence today, having been planted a decade or more ago, are in their most productive stage of their lives, and, hence, it is anticipated that losing these trees to tristeza could result in relatively large decreases in production.

Assumed progression of tristeza. It is assumed that tristeza will infect and eventually kill all trees planted on sour orange rootstock. Two scenarios were considered with respect to how fast tristeza kills off these trees. One scenario assumes that nearly all the trees on this rootstock are killed off over the eight-yr period, starting in 1999-00. The other scenario assumes that it takes 12 yrs to kill off these trees. A logistic function was used to model the loss rate for trees on sour orange rootstock. This function allows the loss rate for trees on this rootstock to increase relatively quickly in the first yrs when tristeza is spreading; then the loss rate levels off as the disease spreads to most of the trees or acres. Trees on other rootstocks are assumed to follow historical loss rates. Projected acre loss rates, by region of the State, are shown in Table 3. The present incidence of tristeza is assumed to be highest in the southern and western regions.

Production methodology and yield assumptions. Grapefruit crop projections were calculated based on data reported by FASS on Florida's grapefruit acre and tree populations, and yields. Starting with the tree and acre data for 1999 (FASS, 1999a), the grapefruit tree and acre populations were projected into the future for the assumed trees per acre planting and loss rates. A set of tree-based production estimates were then made by applying average historical yields per tree to the projected number of trees, by tree age. A set of acre-based production estimates were made by applying average historical yields per acre to the projected number acres, by tree age.

Historic boxes per tree may be higher than future tree yields due to increasing tree densities, so that the projections based on tree yields may overstate future production. The projections based on historic yields per acre may underestimate future production to the extent these yields are lower than future yields — in some young groves, higher densities in the future may not constrain boxes per tree, allowing more boxes per acre to be produced than has occurred in the past.

Planting assumptions. The planting assumption that tree or acre losses are replanted leads to some relatively high planting levels, as the estimated losses due to tristeza are large in some yrs. These large losses in productive capacity will significantly reduce the grapefruit crop and increase on-tree price, providing a likely stimulus to replant. This assumption is consistent with historical data which indicate planting rates tend to vary directly with current and lagged on-tree prices — a small crop tends to result in a relatively high price, depending on demand, which in turn tends to result in a high planting rate.

Production projections. Production projections were made for three varieties and four regions to account for variation in yields, as well as tree and acre loss and planting rates, across varieties and regions. The three varieties were white seedless grapefruit, colored seedless grapefruit and seedy grapefruit. The four regions were the south, west, north and central, and Indian River. These regions are the same as those for which FASS reports yields per tree. Average boxes per tree, by region, for the 1993-94 through 1998-99 period were used in making the tree-based crop projections (FASS, 1999b and 2000). For the acre-based crop projections, yields per acre were calculated indirectly by multiplying FASS boxes per tree times trees per acre. Boxes of fruit per tree were not reported for seedy grapefruit, and an average yield per acre, across all ages, was used in estimating the production of this variety.

State grapefruit production projections for the next 10 yrs are shown in Table 4. If tristeza were not present in Florida or does not result in greater tree losses than experienced historically, grapefruit production is projected to be relatively flat in the 52 to 53 million box range, based on the acre method. Based on the tree method, production is projected to range between 57 and 62 million boxes without tristeza. High tree densities may make the tree-based projections unobtainable, while the acre-based projections may understate production potential. A *best guess* might be somewhere between these two projections.

Assuming tristeza runs its course in the next eight yrs, Florida grapefruit production is estimated to decrease to a low point of about 36 million boxes in the 2003-04 season based on the acre method and 39 million boxes based on the tree method. If tristeza takes 12 yrs to run its course the production low point occurs two yrs later, 2005-06, and is about 2 million boxes higher than that for the eight-yr assumption.

It should be stressed that the foregoing production projections are estimates of average production. In any given season, grapefruit yields and production may vary from the average due to growing conditions. Historically, this variation has been relatively large. In the future, production can be expected to continue to vary from the average. For example, based on yield variation alone, the 95% confident interval for the acre-based grapefruit crop projections is, depending on season, $\pm$15% to $\pm$20% of the figures shown in Table 4.

Price projections. In this section, price projections for the Florida grapefruit industry are presented. Two scenarios are presented: (1) a baseline in which tristeza is not considered, and (2) the case in which the effect of tristeza is included.

In the baseline scenario, the above production forecasts, under the assumption that tristeza is not present, are analyzed with the pricing model. In this model, both the domestic and export markets for red seedless and white seedless grapefruit are included. The model takes the production of red seedless grapefruit as given and then allocates that production among the U.S., Canadian, and the European Union (EU) markets. A fixed percentage of the crop is assumed to be field run.[3] Packout rates determine the proportion of fruit that can be shipped to the fresh market and that fruit which is eliminated. In those yrs with large crops, the model allows for abandonment. A similar allocation processed is also used for white seedless grapefruit except that the domestic U.S. and Japanese markets are only markets considered for fresh sales. A much higher proportion of white seedless grapefruit are field-run compared to red seedless.

In Table 5, the baseline results of the pricing model are presented for red seedless and white seedless grapefruit.[4] The production forecasts (acre method) are relatively flat for both red seedless and white seedless grapefruit over the next 10 yrs. Red seedless production is expected to decline slightly from 31.7 million boxes next season to 30.5 million boxes in the

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[3] Field-run is a term used for fruit sent directly from the grove to the processing plant.

[4] Seedy grapefruit production has been steadily declining in Florida over the past 15 yrs. For the 1999-00 season, seedy grapefruit production is approximately 600 thousand boxes. As such, it is ignored in this analysis.

2009-10 season. White seedless grapefruit production is expect to expand slightly from 20.6 million boxes next season to 21.5 million boxes in 2009-10.

There is no evidence that the demand for fresh grapefruit or grapefruit juice is expanding or contracting.[5] Therefore, with a relative flat production forecast, on-tree prices are also expected to show little change over the next 10 yrs.

In Table 6, the impact of tristeza is included in the forecast. With the large number of trees planted on sour orange rootstock, especially among the older trees, the impact of tristeza on total production is substantial. Red seedless grapefruit production declines from 30 million boxes next season to 22.4 million boxes in 2004-05, before recovering to 29.1 million boxes in the 2009-10 season. A similar effect is expected for white seedless grapefruit with production declining from 19.2 million boxes next season to 12.8 million boxes in 2004-05 and recovering to 19.2 million boxes in 2009-10. The price impact of tristeza is also substantial. On-tree prices would peak at $6.41 and $5.58 per box for red seedless and white seedless, respectively. These price increases are comparable to those seen after the freezes of the 1980s.

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[5] One caveat to this statement is that there has been a disturbing decline in domestic fresh grapefruit shipments over the past five yrs. During this period, however, production in Texas has recovered and likely displaced some product from Florida.

Concluding remarks. In conclusion, tristeza is probably going to march through Florida's citrus industry. Its impact on grapefruit will be substantial unless the disease takes a long time moving across the state. Given Florida's dominance in world grapefruit markets, there will be a substantial price increase in response to reduced production. The analysis conducted in this paper does not consider possible supply response in other grapefruit-producing regions. In particular, Mexico's struggling grapefruit industry could receive a major boost from the forecasted high prices and foreign investment. Florida could also face new competitors in the European market such as Turkey.

Another unknown parameter is the speed at which tristeza might move through the industry. Two scenarios were considered in this study: eight yrs and 12 yrs. In reality, the process could be much faster or much slower than these two scenarios. If tristeza spreads much more quickly, the effect on production will be more pronounced and the spike in on-tree prices will be higher. If the spread of tristeza is a much slower process, the impact on production will be mitigated and the resulting price rise much more shallow.

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Table 1. Florida grapefruit trees and acres.

Year	Acres (1,000	Trees (millions)	Trees per acre
1966	103.2	7.1	68.8
1968	119.9	8.5	70.9
1970	124.1	8.9	71.9
1972	124.1	9.0	72.6
1974	130.3	9.7	74.1
1976	137.9	10.4	75.4
1978	136.3	10.4	76.4
1980	139.9	10.8	77.0
1982	139.9	10.8	77.4
1984	134.7	10.6	78.5
1986	117.8	9.6	81.7
1988	119.6	10.1	84.3
1990	125.3	11.2	89.3
1992	135.2	13.1	97.0
1994	146.9	15.0	102.1
1996	144.4	15.1	104.7
1998	132.8	14.1	106.0
1999	121.3	13.0	106.0

Source: Florida Agricultural Statistics Service (FASS, 1965 through 1999a).

Table 2. Estimated Florida seedless grapefruit trees on sour orange rootstock as of 1999.

Category	Bureau of Citrus Budwood Registration[z]			Hebb-Stover[y]
	Indian River	Other	State	Indian River
	trees (1,000)			
Not on sour orange	6,253	3,123	9,376	4,574
On sour orange	2,563	788	3,351	4,242
Total	8,816	3,912	12,727	8,816
	(%) of total trees			
On sour orange	29.1	20.2	26.3	48.1

[Z]Bureau of Citrus Budwood Registration, 1999.
[Y]Indian River Research and Education Center, Ft. Pierce, FL, 1999.

Table 3. Grapefruit acre loss rate assumptions, for eight-yr phase-out assumption.

Season	Loss rate for trees on sour orange				
	State[z]	Southern	Western	Indian River	Northern & Central
			(%)		
1999-00	4.7	10.1	10.1	4.1	1.6
2000-01	6.9	22.9	22.9	10.1	4.1
2001-02	10.3	43.9	43.9	22.9	10.1
2002-03	13.1	67.3	67.3	43.9	22.9
2003-04	11.4	84.4	84.4	67.3	43.9
2004-05	6.6	93.5	93.5	84.4	67.3
2005-06	3.7	97.4	97.4	93.5	84.4
2006-07	3.1	99.0	99.0	97.4	93.5
2007-08	3.0	99.6	99.6	99.0	97.4
2008-09	3.0	99.9	99.9	99.6	99.0
2009-10	3.0	99.9	99.9	99.9	99.6
2010-11	3.0	100.0	100.0	99.9	99.9
2011-12	3.0	100.0	100.0	100.0	99.9
2012-13	3.0	100.0	100.0	100.0	100.0
2013-14	3.0	100.0	100.0	100.0	100.0

[z]Loss rate on all trees due to normal attrition and tristeza; normal attrition was about 3.0%.

Table 4. Florida grapefruit production estimates.

Season	No tristeza^{z,y}		Tristeza^{z,y,x}	
	Acre method^{w}	Tree method^{v}	Acre method^{u}	Tree method^{t}
	boxes (millions)			
2000-01	52.8	57.3	49.7	53.7
2001-02	52.5	58.2	45.3	49.6
2002-03	52.2	58.9	39.7	43.8
2003-04	52.1	59.6	35.8	39.4
2004-05	52.0	60.0	35.6	38.9
2005-06	52.0	60.4	38.0	41.5
2006-07	52.1	60.8	41.5	45.0
2007-08	52.2	61.2	44.6	48.3
2008-09	52.4	61.5	47.0	51.0
2009-10	52.5	61.8	48.8	53.2

[z]Assumes acres or trees lost are replanted.
[y]Assumes yields are the average over the 1993-94 through 1998-99 period.
[x]Assumes tristeza kills most of the trees on sour orange rootstock in the next eight yrss.
[w]Assumes acre loss rate is 3% per yr.
[v]Assumes tree loss rate is 2% per yr.
[u]See Table 3 for loss rate assumptions.
[t]Loss rates assumed to be about 1% less than in Table 3.

Table 5. Projected red seedless and white seedless grapefruit production and on-tree prices without tristeza (baseline).

Season	Red seedless		White seedless	
	Production	On-tree price	Production	On-tree price
	boxes (1,000)	$/box	boxes (1,000)	$/box
1999-00	31,500	3.51	21,000	2.91
2000-01	31,700	1.76	20,600	2.83
2001-02	31,500	1.84	20,500	2.84
2002-03	31,200	1.96	20,500	2.83
2003-04	31,000	2.04	20,500	2.83
2004-05	30,800	2.12	20,700	2.80
2005-06	30,600	2.21	20,900	2.78
2006-07	30,500	2.25	21,100	2.76
2007-08	30,400	2.30	21,300	2.74
2008-09	30,500	2.26	21,400	2.73
2009-10	30,500	2.26	21,500	2.72

Table 6. Projected red seedless and white seedless grapefruit production and on-tree prices with tristeza.

Season	Red seedless		White seedless	
	Production	On-tree price	Production	On-tree price
	boxes (1,000)	$/box	boxes (1,000)	$/box
1999-00	31,500	3.51	21,000	2.91
2000-01	30,000	2.41	19,200	2.92
2001-02	27,600	3.35	17,200	3.19
2002-03	24,600	5.11	14,700	4.56
2003-04	22,500	6.35	12,900	5.53
2004-05	22,400	6.41	12,800	5.58
2005-06	23,600	5.68	14,000	4.96
2006-07	25,400	4.61	15,600	4.11
2007-08	26,900	3.69	17,100	3.33
2008-09	28,100	3.11	18,400	2.94
2009-10	29,100	2.76	19,200	2.90